CHRONIC MICROELECTRODES FOR PROLONGED RECORDING FROM SINGLE UNITS

ABSTRACT

A new electrode is described which allows continuous recording from single neurons or nerve fibers for an extended period of time. It also allows recording during gross movement and high acceleration and vibration. The basic principle of such an electrode is that its density equal that of the surrounding tissue. Moreover, to avoid standing oscillations, the electrode must be counterbalanced against torque momentum and be floating.

A new electrode has been developed to allow continuous recording from the same single neuron or nerve fiber for a long period of time, up to 2-5 days. In addition, the electrode is designed to withstand sudden and large movements and even high intensity vibration (Fig. 1) and acceleration without being displaced and without damage to the nerve unit involved.

Current microelectrode techniques do not fulfill these specifications. In the chronic implantation method described by Hubel (1959) (1) and modified later by Evarts (1960) (2), a positioner for a hydraulic micromanipulator is chronically anchored to the animal's skull, but the microelectrode is acutely implanted since it is inserted for each recording. A number of untoward conditions are thus eliminated, e.g., drugs, lesion, restraint, etc., but it is still basically an acute technique requiring delicate handling and avoidance of abrupt movement of the animal (Bizzi et al., 1964) (3).

The electrode shown in Fig. 2 consists of a very short ordinary tungsten microelectrode (Hubel, 1957) (4) attached to a piece of polyethylene tubing. The enclosed air pocket reduces the overall density to that of an isotonic solution. To avoid a torquing momentum during acceleration, the tubing is counterweighted to bring the center of gravity toward the geometrical center of the electrode. Also the initial lead wire is small and flexible so that restraint on the electrode is minimized.

The microelectrode with its buoyant component is assembled as follows: A piece of 0.005-inch tungsten wire which has been

machine sharpened to a 3-14 micron tip and a 0.03 inch ±0.010 to 0.005 taper is rinsed and brushed in ethyl acetate. An insulated 0.001-inch platinum wire is attached to the tungsten with conductive epoxy at 0.065 inch from the tip; the tungsten is cut at the required length, usually 0.07 inch; the conductive epoxy is coated with Epoxylite to protect and add bulk to the junction; the tungsten with its lead wire is inserted into one end of a polyethylene tubing and bonded to it with Epoxylite no. 223; the polyethylene tubing is progressively cut until enough buoyance is assured by the air pocket to compensate for the weight of the electrode and the counterweight; the other end of the tubing is plugged with Epoxylite no. 223 and the counterweights; the platinum wire is passed out of the tubing between the counterweights and the inside wall of the tubing.

A drop of paraffin with a meniscus of 0.02 inch is melted to a copper wire handle. The handle is lowered, paraffin downwards, to the counterweighted end of the electrode where it is fused to the electrode.

The tungsten part of the electrode is then sharpened and insulated in the usual way (Hubel, 1957) (4) and tested for leakage. The platinum lead wire is soldered to a heavier copper wire which is insulated with tubing and vinyl. This leaves approximately 0.75 inch of unrestrained platinum between the tubing and the electrode.

When checked for density in 0.65N saline these electrodes were found to stay suspended in a horizontal position and to rotate freely on their vertical axes with 0.1 to 0.4 inch length of platinum wire extending from the tubing.

The microelectrode is implanted in the usual way with a hydraulic micromanipulator: if it is not completely immersed in the tissue, the part of the electrode sticking out from the structure is covered by a blob of agar that links mechanically the electrode to the nerve structure. A heating coil is fixed on the micromanipulator clamp. The coil surrounds the upper end of the wire handle so that enough heat is radiated to the handle to dissolve the paraffin connecting the handle with the electrode. As soon as the electrode is firmly in the appropriate place, recording can begin. It has been found that recording from the same unit is possible for an average of 3-4 days, even during or after severe vibration (Fig. 1).

The critical points are: (a) To choose a neuron that has not been even slightly damaged during implantation. A good index of this is an approximately constant activity for at least half an hour. (b) To use a preamplifier with an input current of 10^{-14} A or less since the critical factor here is the current density at the tip. For the same reason it is better to use the largest size of the tungsten microelectrode which is compatible with a good single unit recording. (c) To use material in the construction of the electrode (e.g., the insulating varnish) that does not react with the tissue. For this reason, platinum black on the tip of the electrode is not advisable flowing to its catalytic properties.

Electrodes such as the one described here have been used satisfactorily to record the activity of single fibers of the vestibular nerve of the frog during parabolic flights in a jet plane. The same preparation has been used on consecutive days, and during as many as 14 parabolic paths flown on the same day, with acceleration changes from 0 to 2.5 G.

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LEGENDS

Fig. 1. Otolith unit. Activity recorded from the corresponding nerve fiber during a 55/sec vibration test. Three top records: outputs from accelerometers placed in the three directions of space. (The accelerometers do not show the real intensity of vibration given their sensitivity and time constant. Their purpose is to indicate the gravitational component during tilt as shown in D.) The fourth record shows the activity of the otolith unit. The container with the frog completely submerged in water was attached to a shaker providing vibrations of various frequency and intensity. As shown, increasing the intensity of vibration from 0 to 1 G (A) the otolith unit increases its rate of firing irregularly. At 4.5 G (B) the rate of firing is equal to the oscillation frequency. Going back to 1 G, the firing becomes irregular once more, with no relation to the frequency of vibration (C). D: response to tilting appears to be normal after the end of vibratory test.

Fig. 2. Photograph and schematics of the chronic microelectrode. For explanation see text.

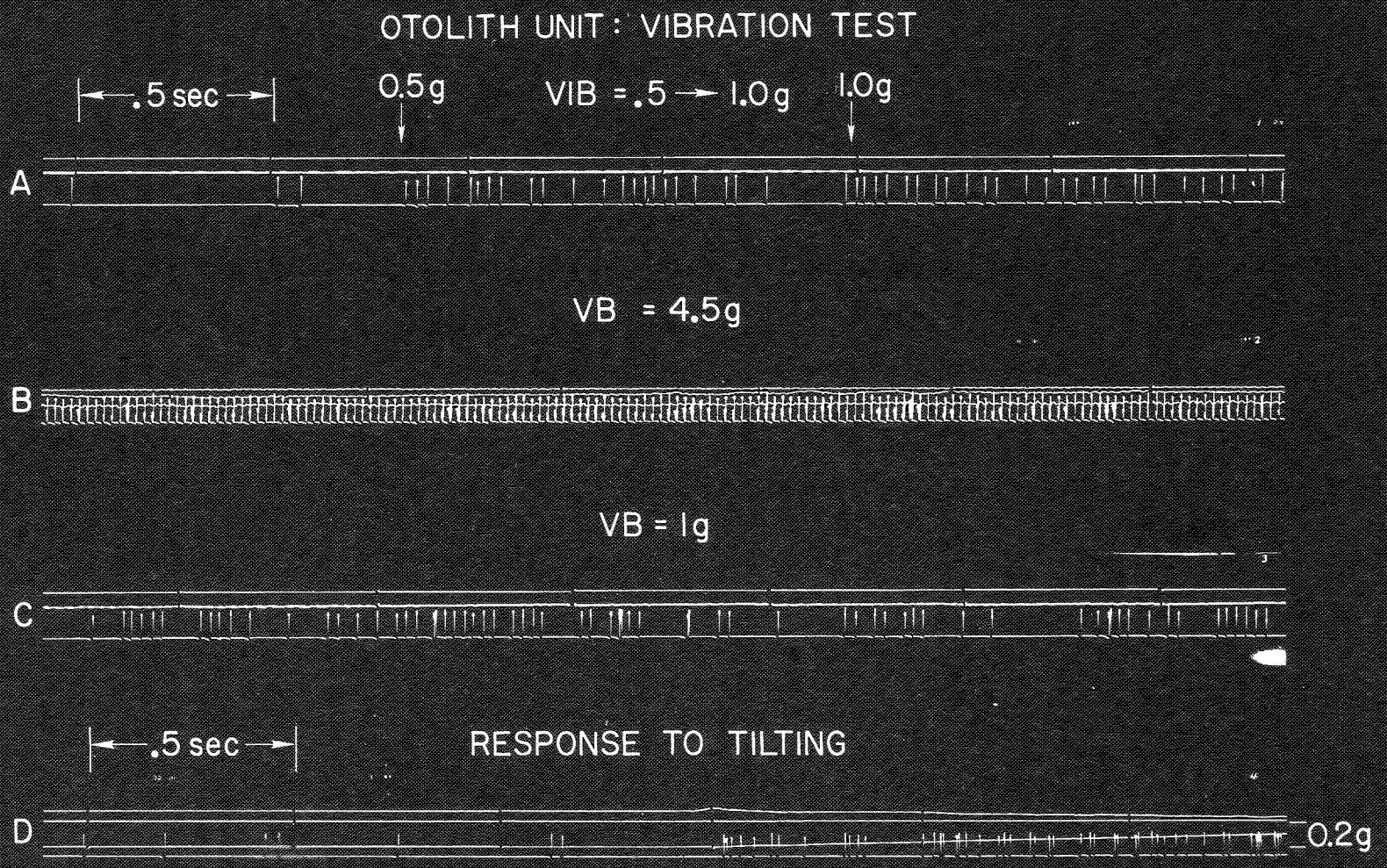

Fig. 1.

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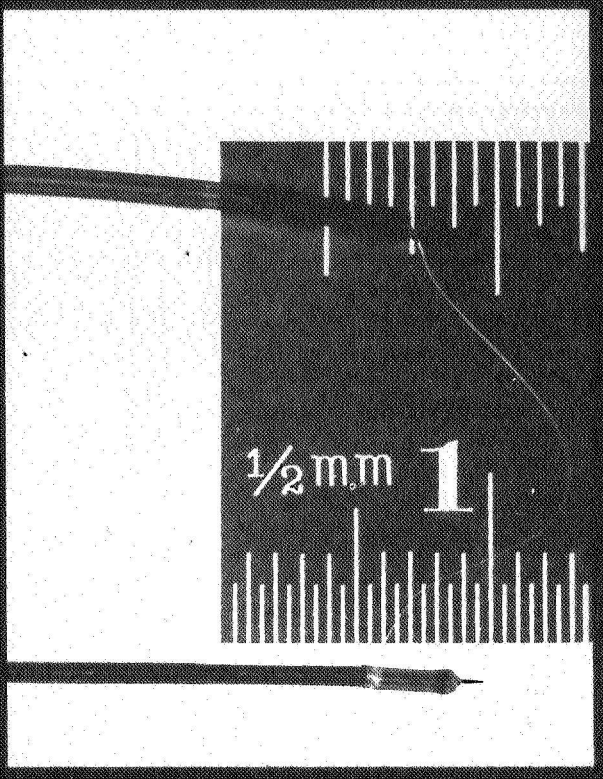

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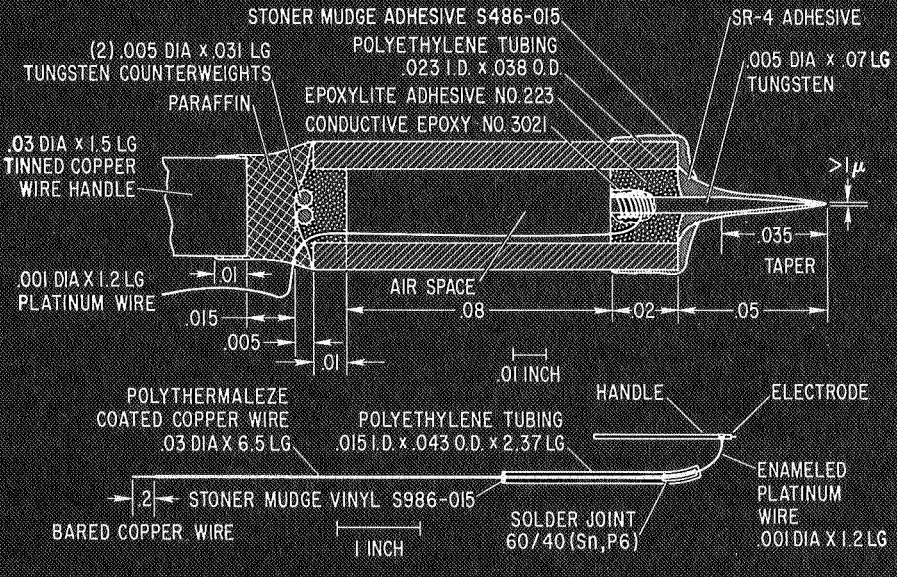

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Fig. 2.

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